FINAL REPORT

BONE, CARTILAGE AND CONNECTIVE TISSUE: EFFECTS OF QUANTITY, TYPE AND REMOVAL SYSTEMS FOR GROUND BEEF

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FOOD QUALITY ASSURANCE BRANCH
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OVERALL SUMMARY AND CONCLUSIONS

In summary, several observations and conclusions can be drawn. First, considering previous studies performed at MSRL (which indicated measurable effects of variations in raw materials and processing on sensory properties of ground beef), it was anticipated that the sources of variation (defect category, processing method) would have more of an effect on various properties of patties in this study. While many of the sensory, cooking, Instron and storage life properties were affected by the two variables studied (especially the interaction of defect category and processing method), most of the significant differences were illogical.

Increased levels of bone and cartilage could be detected by the panelists, however the processing systems were not always consistent in removing these defects. The bone pieces detected were frequently quite small. Certainly, the volume of pieces detected were not of the quantity expected if random distribution of the added bone and cartilage is assumed. Apparently, much of the bone is reduced in size to be undetectable. It is possible that an insufficient amount of product has been examined by the tedious sensory approach to obtain a precise estimation of the number of bone particles. Since that is a possibility, we have made arrangments to utilize an X-ray technique to evaluate the 75-100 lbs. of remaining product/defect category-processing method combination.

Increased levels of a single connective tissue defect were generally not correspondingly detected by the panelists and it was only when all the defects were combined did panelists find a higher level of connective tissue. There is apparently a substantial amount of non-defect connective tissue in beef trimmings that can be detected by panelists. It was also

interesting to note that frequently the connective tissue defects in the patties would exceed .25 in. in at least one dimension.

It would appear from the results that a major question exists as to whether the "all previous six defects together" category represents the worst possible product in terms of defect levels. About everyone involved with the project at MSRL (panelists, technical people) felt that they had consumed ground beef patties either in previous studies or away from the MSRL as consumers that contained much higher levels of defects. Perhaps there is some level of defect inclusion that must be attained, after which additional amounts are easily detected. This study may not have had defect levels high enough to be easily differentiated from PP-B-2120. It would appear that PP-B-2120 does indeed have some built in "safety" to it, since many of the added defect categories were not recognized as being different from PP-B-2120 in the characteristics studies. Perhaps a similar logic can be used regarding the defect collector systems - there needs to be higher levels of defects in the raw materials before the efficacy of these systems can be exhibited.

In retrospect, a better approach to studying the problem of added defects might have been to conduct the study in a plant that does <u>not</u> produce ground beef for government purchase <u>nor</u> uses defect collector systems. In this situation, in addition to the project formulations, one can obtain regular production ground beef from that plant under their typical operations. In the situation of our study at H and H Packing Company, we were asking boners and trimmers to do a less rigorous job of trimming for defects than normal. It is quite likely that they were doing a "better" job of removing defects than a non-government contract plant; even though all the trimming was under close supervision and defects were counted and added back.

INTRODUCTION

Ground beef is one of the most popular and widely consumed beef products in the American diet. An estimated 4 percent of the U.S. family's food budget is spent on ground beef purchases (Salathe, 1979). Over 60 percent of the raw beef available for further processing is manufactured annually into 8 billion pounds of ground beef (Sink, 1980). The federal government is a major purchaser of ground beef. In 1981, federal agencies, primarily the Department of Defense (DOD) which feeds military personnel and the U.S. Department of Agriculture (USDA) which administers the National School Lunch Program, purchased approximately 5.5 percent of commercially produced hamburger and ground beef patties (GAO, 1984).

Many factors influence the perception of ground beef quality by the consumer. Berry and Hasty (1982) identified leanness as the single most important attribute which determines consumer puchases of ground beef. Other factors which may affect purchasing decisions for ground beef include cost (Berry and Hasty, 1982; Glover, 1968; Law et al., 1965), product color (Mize, 1972), and visual appearance (Berry and Hasty, 1982). Connective tissue has been identified as one of the major determinants which influence the acceptance of ground beef (Cross et al., 1976). Consumers with a high consumption level of ground beef view the texture and amount of detectable connective tissue to be important attributes of ground beef (Berry, 1979). In popular terminology, connective tissue may be referred to as "gristle" or "sinew."

A high level of connective tissue in ground beef is associated with reduced tenderness of the product and may adversely affect the nutritional quality of the meat protein. Cross et al. (1976) established a good correlation of subjectively determined connective tissue with tenderness ($r = 0.74$) and also with overall acceptability ($r = 0.71$). The amount and size of connective tissue particles in ground beef apparently influence its tenderness (Berry, 1979). Connective tissue is deficient in the amino acid tryptophan and contains a large amount of hydroxyproline in comparison to other muscle proteins (Dahl, 1960). As the hydroxyproline content of meat increases, the chemical availability of its essential amino acids suffers a corresponding decrease (Dvorak and Vognarova, 1965; 1969). Thus, although meat is considered to contain readily digestible protein with a good balance of amino acids, a high level of connective tissue may detrimentally affect the biological value of its protein.

The presence of foreign materials in ground beef patties including hard particles of bone, cartilage, and tough gristle is objectionable from the standpoint of aesthetic quality as well as health and safety factors. Consumers have sustained dental injury from the ingestion of commercial hamburger patties which contained a hard object such as bone or gristle particles (Fishman, 1984).

One recent technological development which has been introduced into the meat processing industry is the mechanical removal system for objectionable materials such as bone, cartilage, and connective tissue particles from ground beef. Ground beef manufacturers have started to utilize these collector systems in their grinding operations as a means of maintaining product quality through the physical separation of bone chips

and gristle from the ground beef (Anonymous, 1980). Two commercially available mechanical removal systems for objectionable materials are the Weiler Bone/Tissue Collecting Assembly (BCA)[1] and the Speco Spiral Groove System[2]. The manufacturer of the Weiler BCA has claimed that the system will separate and eliminate "cartilage, gristle, stray bone chips and other tough connective tissues" from meat trimmings (Schulte, 1984). Manufacturer's claims for the Speco Spiral Groove System include removal of "bone particles, gristle, bits of metal, and other foreign particles" (Anonymous, 1984). Although the design varies with the manufacturer, in general, the collector system is installed on the grinding equipment to remove foreign particles as the meat exits from the discharge end of the regular grinding plate during the final grind. Even without aid from a collector system, the regular grinding system may remove bone and gristle during the final grind (Anonymous, 1976).

The federal government is a primary purchaser of ground beef because of its USDA food distribution programs and its military feeding responsibilities (GAO, 1984). In the past, during the manufacture of ground beef for federal procurement, boneless beef trimmings normally underwent a certification procedure in the processing plant where they were examined for the presence of major and minor classes of defective materials or "defects". This included specific types, quantities, and dimensions of bone, cartilage, and connective tissue that were established in the <u>Interim Federal Specifications for Frozen Ground Beef Products</u>

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[1]Weiler and Co., Whitewater, WI.

[2]Manufactured by Speco, Inc., Schiller Park, IL, and marketed as the Cozzini bone and gristle removal system by Cozzini Brothers, Inc., Chicago, IL.

(AMS, 1983). As part of its efforts to implement cost-saving measures in the federal food procurement program, the U.S. General Accounting Office (GAO) issued a report (GAO, 1984) which recommended restriction of the certification process to compliance with current meat and poultry inspection regulations and suggested potential use of mechanical removal systems for exclusion of defective materials from the final product.

However, testing of the efficiency of the defect collector systems for elimination of objectionable particles in ground beef thus far has been restricted to several company studies (Craig, 1984; Hess and Cozzini, 1983) and a single governmental investigation (Klein and Lail, 1984). Researchers have not yet ascertained the effects of collector systems for defective materials on the sensory properties of ground beef.

Therefore, the aim of this study was to establish the effects of manufacturing ground beef with mechanical removal systems on the sensory quality of cooked ground beef patties with special emphasis on the nature of the defective materials which may remain or be removed from the product during processing with collector systems.

EXPERIMENTAL PROCEDURES

Formulation and Processing

Eight lots of ground beef were processed at H & H Meat Products, Co., Mercedes, TX, in 12-hour workshifts during a 4-day period from June 25-28, 1984. The baseline formulation for each lot consisted of approximately 10,000 lbs. of boned beef trimmings (triangles, rib caps, knuckles) from 80 U.S. Utility beef sides. Approximately 250 U.S. Choice plates were added to each lot, as necessary, to adjust the fat content to 20 ± 1%. A standardized fat content for ground beef studies is critical because Cross et al. (1980) reported that increasing fat levels in ground beef formulations may produce a more tender product with less panel-detectable connective tissue.

Lot 1 was formulated to be in compliance with the federal regulations (PP-B-2120) whereas the remaining lots were formulated to exceed the level for the given defective material as specified in the most restrictive form of the Interim Federal Specifications (AMS, 1980). Lots 2-7 were prepared to contain excessive levels of bone, cartilage, backstrap, protruding tendons, abdominal tunic, and scratchy (calcified) periosteum, respectively. Lot 8 was formulated to exceed the levels for all six types of defects. All defects were either left attached to the beef cuts during trimming or added directly to the lean cuts during initial mixing. The sources, levels, and dimensions of each type of defective material, where applicable, are presented in Table 1 for each lot of ground beef.

Because of limitations in the capacity of the production equipment, the lots were subdivided prior to processing into three sublots (A, B, C) for each type of defect. Each sublot was initially blended for approximately 10 min. in a Rietz Mixer (Model RS-28K5406). Any defects

Table 1. Description of Defective Materials Incorporated into Lots of Ground Beef

Lot No.	Type of Defect	Description
1	None	In compliance with federal specifications.
2	Bone	300 pieces (added directly); 1.3-2.5 cm x < 7.6 cm. 600 slivers (100 slivers added directly; 500 slivers attached to 250 plates); 0.3-1.3 cm. x < 7.6 cm.
3	Cartilage	Pieces attached to scapula from rib cap; 25.8 cm^2/piece. Pieces attached to scapula from chuck; 12.9 cm^2/piece.
4	Backstrap	320 pieces from chuck; > 2.5 cm. x > 0.5 cm. 320 pieces from rib cap; > 2.5 cm x > 0.5 cm.
5	Protruding tendons	Tendinous ends from arm, clod, knuckle, foreshank, and heel left attached; > 2.5 cm.
6	Abdominal tunic	160 flanks.
7	Scratchy (calcified) periosteum	366 pieces periosteum; 6.4 cm^2. 366 pieces scratchy periosteum; 6.4 cm^2. (183 lbs. added directly).
8	Excessive in all 6 defects	Same as Lots 2-7.

FIGURE 1

Schematic of Weiler Bone/Tissue Collecting Assembly (BCA)

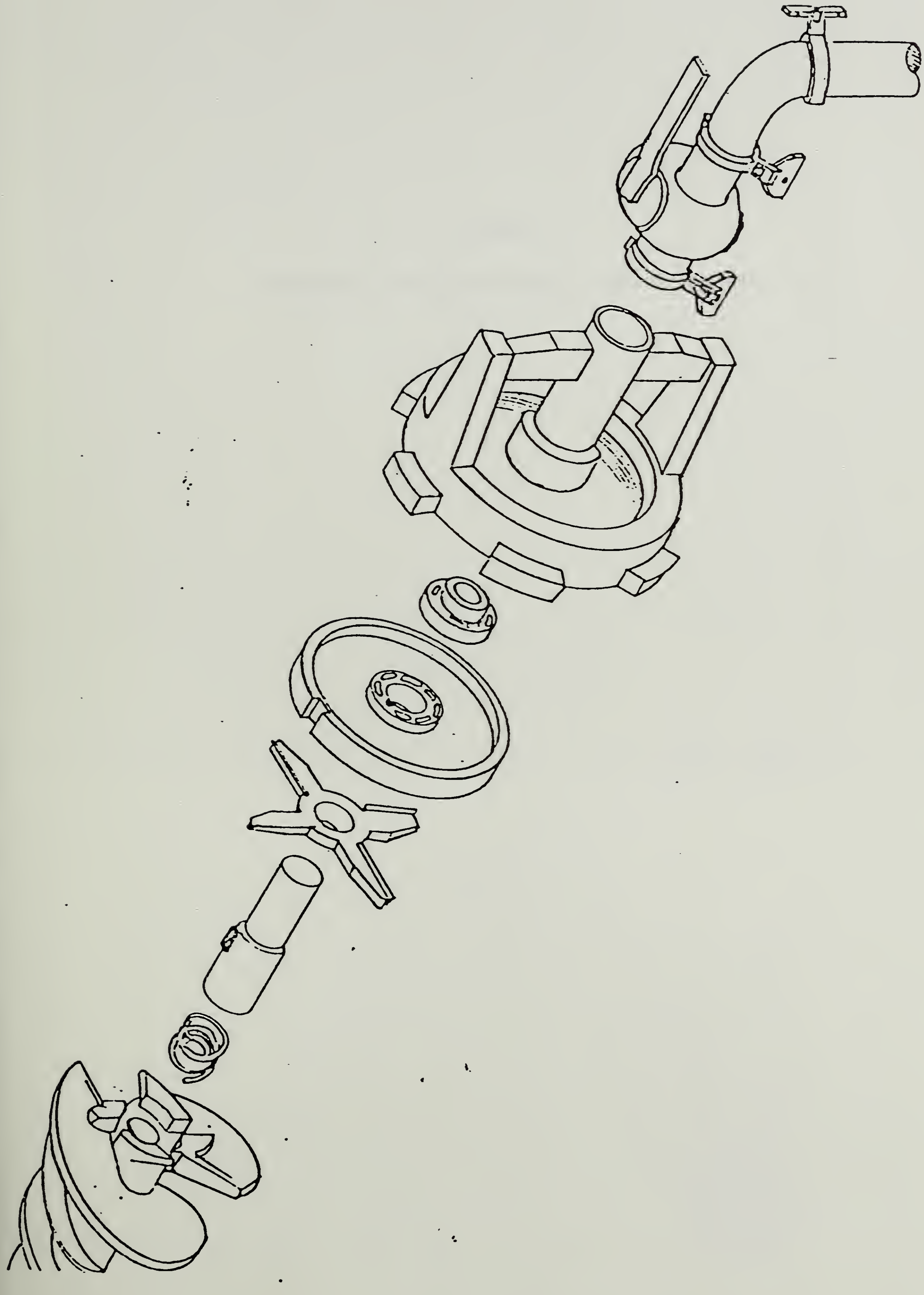
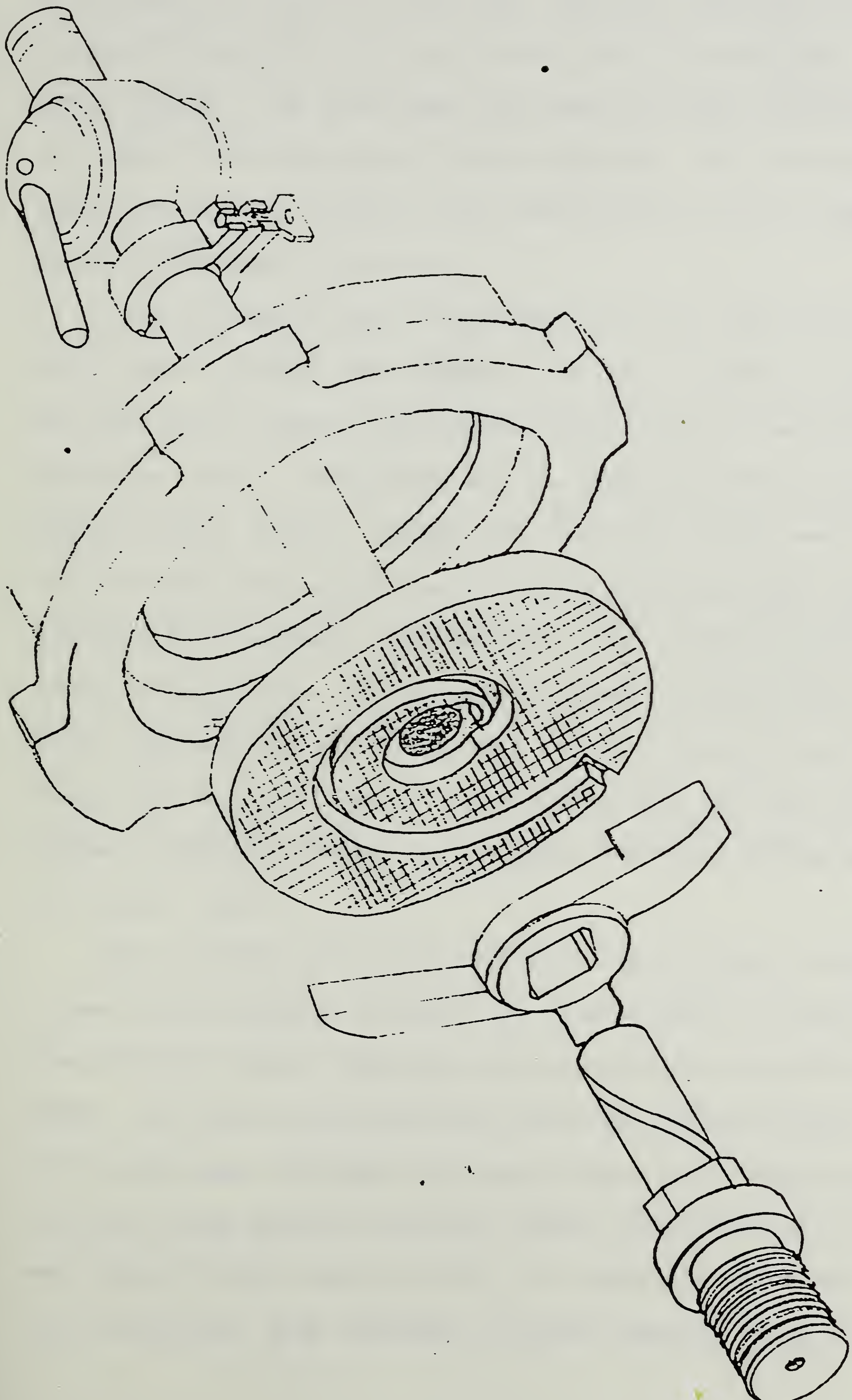


FIGURE 2

Schematic of Speco Spiral Groove System



which were not attached to the beef trimmings were randomly added to the meat during the initial mixing stage. The beef trimmings first were processed through the 1.91 cm. grinding plate of a Boldt meat grinder (Model SH5778). The ground meat was completely mixed and then sampled for fat content with Anyl-Ray fat testing equipment. The fat level of the sublot was adjusted to 20 $\pm$ 1% with the addition of fat or lean materials to the ground beef, as necessary.

Final grinding of the beef through a 0.32 cm. plate was performed with a Weiler grinder (Model AG868). The regular grinding system (0.32 cm.) was used to process the A sublots whereas one of the defect collector systems was used in conjunction with the regular grinding system to process B and C sublots. Ground beef from the B sublots was manufactured with the Weiler BCA Bone/Tissue Collecting System equipped with an automatic valve assembly. The automatic valve assembly operated at an air speed setting of 5 sec. and at specifications of 0.5 sec. with the valve in the open position and 10 sec. with the valve in the closed position. Ground beef from the C sublots was processed with the Speco Spiral Groove System. Schematic drawings for the defect collector systems are provided in Figures 1 and 2.

After grinding, the ground beef was formed into 85 g. patties with a Formax 26 patty machine, packaged, and transported to a nearby plant (Russellville, TX) for freezing according to federal specifications (AMS, 1980). The last six boxes (36 lbs.) from each sublot during production (last eight boxes from Sublot 1A) were shipped via refrigerated truck to the Meat Science Research Laboratory (MSRL), Beltsville, MD. The patties were stored in their boxes at -23° C in a federally inspected freezer until packaging. After packaging in double layers of waxed white

butcher's paper in quantities of 4, 6, 8, 10, and 15 patties per package, the patties were stored at 40° C until laboratory analyses began. Remaining boxes were stored at 0° F. All laboratory analyses were conducted at MSRL.

Cooking Procedures

For all laboratory procedures, the ground beef patties were cooked from the frozen state according to standard methodology developed at MSRL to minimize the formation of crust on the surface while maintaining a consistent degree of doneness. Four frozen patties per grill were cooked with one patty in the same position at each corner over the heating element on preheated, calibrated Farberware electric griddles (Model 101) at 149 $\pm$ 12° C for a total cooking time of 8 min. Patties were cooked for 2 min on one side and for 3 min on the opposite side and then turned every 30 sec for another 3 min. Cooked patties were gently blotted to remove excess grease and other materials from the surface. The frozen and cooked weights of each patty were recorded and used to determine the total cooking loss from the following formula:

$$\text{Percent Cooking Loss} = \frac{\text{Frozen Weight} - \text{Cooked Weight}}{\text{Frozen Weight}} \times 100$$

In addition, trained personnel evaluated the degree of doneness of each patty on an 8-point rating scale after cutting; (1 = well done to 8 = rare) by comparison to color photographs[1].

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[1]Available from the Meat Science and Muscle Biology Section, Animal Science Department, Texas A & M University, College Station, TX 77483.

Sensory Evaluation Procedures

All subjects were recruited from respondents to advertisements placed in several local newspapers and have worked on an intermittent basis at MSRL for a minimum time of two years.

For the defects and descriptive attributes panels, panel members evaluated all samples under natural lighting in partitioned booths in a sensory evaluation facility. For texture profile analysis, the panelists were seated at a large table in a separate room from the preparation area to facilitate discussion of the samples after the evaluation period. For all evaluation sessions, the panelists were provided with expectoration cups for use at their own discretion.

Defects Panel

The defects panel was comprised of 13 female members (ages 25-60 years) who undertook an intensive 3-month training program prior to the start of the study to learn the procedures for detection, isolation, identification and quantification of particles of bone, cartilage and connective tissue in the products. The standard procedure outlined in Table 2 for the detection of defective materials (bone, cartilage, connective tissue) in cooked ground beef patties was initially developed by the texture profile panel after exposure to and practice with a wide array of experimentally and commercially prepared samples of ground beef patties containing different types and levels of bone, cartilage, and connective tissue.

For a given treatment, four cooked ground beef patties were trimmed on one side to form a straight edge, placed one patty at a time in a specially designed sample sizing box, and cut into 0.6 cm. x 1.3 cm. samples. Approximately 44 sample pieces were obtained per patty.

Table 2. Detection Procedures for Defects

Place 1/4" x 1/2" sample into your mouth. Position the sample in your mouth so that the long axis of the sample runs in a direction parallel to the length of your tongue. The crusty sides of the sample should be in a position perpendicular to the flat surface of your tongue.

Use your tongue to maneuver the sample through the incisors at a rate which permits complete examination of the sample in approximately 25 chews. Do not exceed the 25 chew limit. Use fewer than 25 chews only if the detected defect is extremely large in comparison to the overall sample size.

Use the incisors in a gently cutting and rolling action to separate the defect from the sample. The tongue and edges of incisors may be used as "feelers" to confirm the presence of a defect.

Once the defect has been detected, separate it from the meat fibers as completely as possible while the sample remains in your mouth.

Remove the isolated defect from your mouth and retain on the paper plate half. Avoid use of your hands except to remove isolated defects from your mouth.

Any defects remaining after you have swallowed the sample should be counted as detected on the final chew.

Rinse with water and use Melba toast, as necessary, to eliminate carryover from one sample to the next one.

Approximately 10 samples were randomly selected and served to each panelist at one time. After 10 min., the procedure was repeated with another four cooked patties from the same treatment. Thus, for each experimental treatment, twenty, 0.6 cm. x 1.3 cm samples were evaluated per panelist in a session.

For each 0.6. cm x 1.3 cm. sample, the panelist recorded the total number of defects in the sample at the end of mastication, the number of defects identified as bone and/or cartilage, and the number of chews required to evaluate the sample completely (restricted to approximately 25 chews per sample). Thus, the dependent variables which were measured included the total number of defects, total number of bone particles, total number of cartilage particles, and total number of connective tissue particles (calculated by difference) on a 20-sample test size of the treatment.

After each panelist completed her evaluation of the 20 samples, trained personnel examined and validated the types and counts of the defects which were isolated from the 20 samples of the product.

The defects panel evaluated three treatments at half-hour intervals every weekday over a 6-week period. On a given day, the panelists were served all products from the processing methods for a given type of defect in a random order. (Refer to Table 3). Each treatment was replicated four times during the course of the study.

Descriptive Attributes Panel

The sensory panelists (8 females, 1 male; ages 30-60 years) evaluated the descriptive attributes of ground beef patties according to the procedures specified in AMSA (1978) and Cross et al. (1978). The

Table 3. Experimental Design for Defects Panel

Session No.	Order of Sample Presentation*		
1	1B	1C	1A
2	4A	4B	4C
3	3A	3C	3B
4	2C	2B	2A
5	7C	7A	7B
6	8C	8B	8A
7	6A	6C	6B
8	5A	5C	5B
9	6C	6B	6A
10	5A	5C	5B
11	1B	1C	1A
12	7A	7B	7C
13	3A	3C	3B
14	8A	8C	8B
15	4C	4B	4A
16	2B	2A	2C
17	7A	7C	7B
18	3B	3A	3C
19	8A	8B	8C
20	6C	6A	6B
21	5A	5C	5B
22	4C	4A	4B
23	1A	1C	1B
24	2A	2B	2C
25	7C	7B	7A
26	3A	3B	3C
27	5A	5C	5B
28	4C	4B	4A
29	6C	6B	6A
30	2B	2C	2A
31	1B	1A	1C
32	8A	8C	8B

*1 = Meets federal specifications for defective materials in ground beef
2 = Excess bone
3 = Excess cartilage
4 = Excess backstrap
5 = Excess protruding tendons
6 = Excess abdominal tunic
7 = Excess scratchy (calcified) periosteum
8 = Excessive in all 6 of the above defective materials

A = Regular grinding system
B = Weiler BCA Bone/Tissue Collecting System
C = Speco Spiral Groove System

descriptive attributes which the panelists evaluated using 8-point structured scales included tenderness (1 = extremely tough to 8 = extremely tender), juiciness (1 = extremely dry to 8 = extremely juicy), connective tissue amount (1 = abundant or 60% to 8 = none or 0%), beef flavor intensity (1 = extremely bland to 8 = extremely intense), other detectable flavors (liver, sour, bitter, metallic, sweet, rancid, putrid, salty, mature beef, or other flavors) and their respective intensities (1 = extremely bland to 8 = extremely intense), and mouth coating effect (1 = very pronounced to 8 = none). The sensory parameters were evaluated in the following manner: (1) initial tenderness at 5 chews and final tenderness at 15 chews, (2) juiciness during the first 15 chews, (3) perceived connective tissue at the end of mastication, (4) presence and intensities of beef and other detectable flavors throughout mastication, and (5) mouth coating effect after swallowing. The panelists were restricted to listing two flavors other than beef flavor and were requested to specify the flavor if it did not appear in the list of other detectable flavors.

Four patties from each treatment at each session were cooked and cut into eight wedges. Two wedges were served to each sensory panelist at 4-min. intervals. After each sample evaluation, the panelists cleansed their palates with warmed apple juice, tap water at room temperature, and unsalted Malba toast.

All evaluations were conducted two days per week (Monday/Wednesday or Tuesday/Wednesday) during a 4-week time span from approximately 9:00-10:00 a.m. Each day, the sensory panel evaluated a total of 12 samples in two 6-sample sessions with a 10-min. recess period between sessions. Bohnenkamp and Berry (1986) determined that there was no difference in the

ability of sensory panelists to distinguish between ground beef formulations presented in either 8- or 12-sample sessions.

On a given day, the panelists were served four products from all processing systems arranged in random order. Panelists evaluated each treatment four times.

Texture Profile Panel

The texture profile panel was trained according to the procedures of Civille and Szczesniak (1973) and was comprised of six female members (ages 25-55 years). The texture profile analysis of cooked ground beef patties included assessment of the following parameters: (1) visual characteristics (surface, edge, and circumference distortion), (2) surface characteristics (moistness, debris, abrasiveness), (3) first bite characteristics (moisture release, hardness, cohesiveness, density), (4) partial compression characteristics (impression), (5) masticatory characteristics (crust, juiciness, rate of breakdown, cohesiveness of mass, harshness of mass, moistness of mass), (6) end of mastication characteristics (gristle, chewiness), and (7) after swallow characteristics (tooth pack, oily mouth coating). The definitions of the textural parameters which the panel has developed and will employ in their assessments of the experimental products are provided in Table 4.

Each textural property was evaluated using an unstructured 15-cm. long horizontal line anchored on the left extreme with the term "low" and on the right extreme with the term "high." The vertical marks which the panelists used to rate the given attribute of a sample were converted to scores by measuring the distance from the extreme left end of the line to the vertical mark to the nearest 0.5 cm. with a ruler.

Table 4. Definitions of Textural Parameters for Ground Beef Patties

I. Visual characteristics - Use an uncut patty at room temperature, observe both sides, and evaluate for:
   A. Surface distortion - Degree to which the flat plane of the sample has warped.
   B. Edge distortion - Degree to which the perimeter lack smoothness and uniformity.
   C. Circumference distortion - Degree to which the patty has changed from a cirular shape.

II. Surface characteristics - Place one-quarter patty 2.5 cm. into mouth with one cut edge and one uncut edge included, rub with lips and tongue, and evaluate for:
   A. Moistness - Degree to which the surface feels wet/oily--not dry.
   B. Debris - Amount of loose material on the surface.
   C. Abrasiveness - Degree to which the surface feels harsh.

III. First bite characteristics - Place another one-quarter patty into mouth as for evaluation of surface characteristics, bite into sample with incisors using a steady, uniform pressure, and evaluate for:
   A. Moisture release - Amount of juiciness present.
   B. Hardness - Amount of force required to bite through sample.
   C. Cohesiveness - Degree to which the sample deforms.
   D. Density - Degree of compactness in the cross-section.

IV. Partial compression characteristics - Place warm precut 2.5 cm^2 sample into mouth; using molars against the cooked surface, gently compress to two-thirds of the original sample thickness; release for a count of 5, and evaluate for:
   A. Impression - Degree to which the sample retains tooth marks and/or distortion (no noticeable effect=0; cracking or breaking=10-15).

V. Masticatory characteristics - Take warm precut 2.5 cm^2 sample, use molars against cooked surfaces, bite into sample for first chew, turn 90° and realign as before for second chew. Continue to chew and evaluate for:
   A. Crust - Degree to which crust is present after the first 2 chews.
   B. Juiciness - Amount of moisture released after 7-8 chews.
   C. Rate of breakdown - Degree to which the sample has disintegrated or fragmented into its component parts following 7-8 chews.
   D. Cohesiveness of mass - Degree to which particles stick together following 15 chews.
   E. Harshness of mass - Degree to which particles seem abrasive following 15 chews.
   F. Moistness of mass - Degree to which mass feels wet following 15 chews.

Table 4. Continued:

VI. End of mastication characteristics
   A. Gristle - Amount of rubbery particles present.
   B. Chewiness - Total number of chews necessary to prepare the sample for swallowing.

VII. After swallow characteristics
   A. Tooth pack - Amount of sample material in between, around, on and in teeth.
   B. Oily mouth coating - Amount of oily residue left on surfaces of mouth.

During the evaluation of masticatory characteristics, the texture profile panel also assessed fragmentation at two chews (1 = crumbly, complete; 2 = crumbly, incomplete; 3 = shears cleanly; 4 = compacts along shear line; 5 = shears, incomplete; 6 = other, describe). In addition, panelists provided a written description of the breakdown process during mastication of the warm 2.5 $cm.^2$ sample which included sample characteristics and a description of bone particles, if present. The percentage of gristle in the total sample (for example, 20% = 7.5; 40% = 15.0) was determined by masticating the 2.5 $cm.^2$ sample with the molars until it was sufficiently broken apart to evaluate the mass systematically with the incisors for the presence and amount of gristle.

The panelists were provided with tap water at room temperature and unsalted Melba toast to use as palate cleansers after a sample. The texture profile panel evaluated three treatments per day. The panelists participated in a 4-week retraining program before they began to evaluate the experimental products. In a given session, panelists evaluated products from all processing systems for a specific type of defect in random order. Each product was presented to the panel for evaluation one time. Texture profile analysis yields highly reproducible results, thereby permitting the use of a small number of replicates.

Instron Measurements

Twenty patties for each defect category-processing method combination were cooked as previously described. Cooked patty thickness values were recorded in order to express shear data as Newtons. Following cooking, patties were cooled for 30 min. prior to being cut into four 3.0 cm. square pieces per patty. The maximum force to shear through the squares

was measured using a Universal Instron machine (Model 1122) and a straight edge blade. Measurements taken included peak load, peak energy, modulus of elasticity, fail energy and Newtons.

Sensory Appraisal of Storage Life

A six-member trained sensory panel evaluated storage properties of patties from the original boxes following six months of frozen storage at 0° F. This panel visually appraised the degree of surface discoloration using a seven-point scale where 7 = no surface discoloration and 1 = 90-100% surface discoloration. Lean color was classified into one of eight different colors: very light grayish red, light grayish red, moderately light cherry red, cherry red, slightly dark red, moderately dark red, dark red, very dark red. Off-odor was determined using a four-point scale where 4 = no off-odor and 1 = extreme off-odor.

TBA Determinations

TBA determinations were made according to the procedures of Tarladgis et al. (1960) on patties obtained after six months of frozen storage at 0° F.

Aerobic Plate Counts

For each defect category-processing method combination, three different samples were obtained following six months of frozen storage at 0° F and subjected to aerobic plate counts. Plates were inoculated at 15° C for 4-5 days.

Statistical Analyses

For most variables, analyses of variance (Snedecor and Cochran, 1972) was conducted. When analyses of variance revealed significant ($P<0.05$) differences, the conservative Bonferroni procedures were employed to test the differences between the various pairs of means. Since total bone and cartilage counts were low and probably followed some abnormal distribution, the Chi-Square test was used when the Chi-Square test revealed significant ($P<0.05$) among processing systems or systems within a defect category, then Fisher's Exact test (2-tail) was used in pair comparisons. Frequency distributions were generated for flavor detection and lean colors.

RESULTS AND DISCUSSION

Code numbers given in Table 5 are sometimes used in following tables to identify defect category-processing method combinations. Data pertaining to the number of bone particles in the various formulations are given in Table 6. Due to minimal amounts of detected bone particles, analyses of variance procedures could not be applied. The use of the Chi-square statistic indicated a significant ($P<0.05$) interaction to be present. However, the Bonferroni test failed to reveal any significant ($P<0.05$) differences in any of the various pair comparisons. It must be pointed out at this time that the Bonferroni test is extremely conservative. This test was selected since results of this study would be given close scrutiny for possibly changing of specifications and thus conservative interpretations might be advantageous. With the rather substantial degree of variation that was apparent for the presence of connective tissue particles, again the Bonferroni test procedure appeared to have merit. Some might interpret that the presence of just one bone particle in the equivalent of 14 patties constitutes a serious problem. In that case, the use or disuse of a conservative statistical procedure is not germane to the situation. As would be expected, the two categories (bone, all previous 6 defects together) did contain more pieces of detectable bone particles. The significant interaction is probably a result of the Weiler BCA system seemingly being more effective when all defects were used at once compared to when just bone was added. For some reason, three pieces of bone were found in the protruding tendon and abdominal tunic category when the Speco system was used.

Table 5. Explanation of defect category and processing method by code

Defect Category	Code	Processing Method	Code
PP-B-2120	1	Regular Grinder Plate	A
Bone	2	Weiler BCA	B
Cartilage	3	Speco Spiral Grove Plate	C
Backstrap	4		
Protruding tendons	5		
Abdoinal tunic	6		
Scratchy priosteum	7		
All previous 6 defects together	8		

Table 6. Total number of bone particles detected as influenced by defect category and processing method

Defect Category	Processing Method: Regular Grinder Plate	Weiler BCA	Speco Spiral Grove Plate
PP-B-2120	0	0	0
Bone	3	3	1
Cartilage	0	0	0
Backstrap	1	0	1
Protruding tendons	1	0	3
Abdominal tunic	1	0	3
Scratchy periosteum	0	0	0
All previous 6 defects together	6	0	2

[a]Due to the limited number of actual bone particles detected, Analyses of Variance procedures are not appropriate. Chi-square statistics have been used. Indications are that a significant interaction ($P<0.05$) exists, however, due again to minimal numbers of detected bone particles, these interaction means cannot be compared. The use of Bonferroni's test to compare all pairs of main effect means failed to show any differences ($P<0.05$) between any types of defects and of the processing methods.

If one attempts to divide out all the bone added into the size of bone particles detected (generally small - .05 in max.) and assumes all of the bone went into the product, then approximately 4.2 bone pieces/patty should be found. However, in patties manufactured through the regular grinder and containing excess bone, the bone pieces/patty figures out to be roughly 0.33. Thus, the question becomes, "Where is the bone?" Obviously, even regular grinding takes out some. However, because of the very small size of the pieces detected, it is quite possible that a considerable amount of bone and probably cartilage too, gets reduced to such a sufficiently small size as to be undetectable.

Total numbers of cartilage particles according to defect category and processing method are presented in Table 7. Processing methods did not influence the amount of detected cartilage, but significant main effect differences ($P<0.05$) attributable to defect category were found. These differences consisted of the PP-B-2120, bone and scratchy periosteum formulations having less detectable cartilage than the cartilage-added and all previous 6 defects together formulations. Again, a significant interaction was detected. The interaction would appear to be largely the result of the Speco spiral grove plate being effective in removing cartilage when all the other defects were present in large amounts, but being ineffective compared to the other two systems in removing cartilage when just cartilage was added. Statistically, the differences ($P<0.05$) found in regular grinding, were where all the 6 defects together had more detected cartilage than the bone and scratchy periosteum formulations.

Another way to consider the effectiveness of the processing methods would be to consider the numbers of total bone and/or cartilage regardless of defect category (or interaction). If one compares the three processing

Table 7. Total number of cartilage particles detected as influenced by defect category and processing method

Defect Category	Defect Code Number	Processing Method			Comparisons Significant at $P<0.05$
		Regular Grinder Plate	Weiler BCA	Speco Spiral Grove Plate	
PP-B-2120	1	1	0	0	1 < 3 and 8
Bone	2	0	0	0	2 < 3 and 8
Cartilage	3	4	4	7	
Backstrap	4	1	0	2	
Protruding tendons	5	2	1	1	
Abdominal tunic	6	1	0	2	
Scratchy periosteum	7	0	1	0	7 < 3 and 8
All previous 6 defects together	8	10	8	1	

[a]Due to the limited number of actual cartilage particles detected, Analyses of Variance procedures are not appropriate. Chi-square statistics have been used. The use of Bonferroni's test to compare all pairs of main effect means failed to show any differences ($P<0.05$) between processing methods, but did show differences ($P<0.05$) between defect categories. Indications are that a significant interaction ($P<0.05$) exists, however, due again to minimal numbers of detected cartilage particles, this interaction may not mean much. The significant interaction differences consisted of the amount of detected cartilage when regular grinding was used being higher in all the previous 6 defects together compared to the bone and scratchy periosteum formulations when regular grinding was used.

methods for all the bone and cartilage defects found, then 31 defects were found by regular grinding, 17 through the Weiler system and 23 through the Speco system. Under this approach, some improvement in using the collector systems can be observed.

Since considerably more connective tissue particles were detected compared to bone and cartilage, those data were capable of being fully analyzed by analyses of variance (Table 8). There were some differences in terms of significant sources of variation dependent on whether the sessions were designed to contain different defect categories or different processing methods. When the sessions contained different processing methods but common defect categories, all sources of variation were nonsignificant ($P<0.05$). This was probably due in the case of defect categories to the mean values for connective tissue being larger for PP-B-2120 and smaller for all 6 defects combined when the sessions contained different processing methods, but common defect categories compared to when the sessions had common processing methods but different defect categories. It was perhaps easier to tell differences in amount of connective tissue attributable to different types and amounts of connective tissue when these variations occurred within a given day's sessions. There is no question that the defects recorded were actually bone, cartilage or connective tissue materials since they were verified visually. However, it is always possible that some of the materials missed detection.

Mean values for connective tissue particles given in Table 9 represent the connective tissue particle count per 20 pieces. These means are the interaction values according to defect category and processing method. Two statistical mean separations were used; the conservative

Table 8. Significance of sources of variation in types of evaluation sessions and over all sessions for connective tissue

	Sessions		
Source of Variation	Sessions of different defect categories but common processing methods	Sessions of different processing methods but common defect categories	All sessions combined
Defect category	.0001	NS	.0002
Processing method	NS	NS	NS
Defect category X processing method interaction	.019	NS	.023

[a]From Analyses of Variance
NS = nonsignificant at $P>0.05$.

Table 9. Mean values for connective tissue particles per 20 pieces as influenced by defect category and processing method

Defect Category	Processing Method: Regular Grinder Plate	Code	Processing Method: Weiler BCA	Code	Processing Method: Speco Spiral Grove Plate	Code	Significant ($P<0.05$) differences found by conservative Bonferroni test	Significant ($P<0.05$) differences found by less conservative degree of freedom adjustments
PP-B-2120	13.4 ± 5.6	(1A)	15.2 ± 8.7	(1B)	16.8 ± 6.9	(1C)		1B<8B
Bone	15.3 ± 6.3	(2A)	15.1 ± 6.0	(2B)	19.9 ± 8.2	(2C)		2B<8B
Cartilage	11.5 ± 5.8	(3A)	12.3 ± 6.3	(3B)	15.5 ± 5.9	(3C)	3B<8B	3B<8B, 3A<8A
Backstrap	16.5 ± 6.9	(4A)	16.6 ± 7.2	(4B)	13.4 ± 6.1	(4C)		4B<8B
Protruding tendons	13.9 ± 6.9	(5A)	10.6 ± 4.8	(5B)	12.5 ± 5.7	(5C)	5B<8B	5B<8B, 5C<2C
Abdominal tunic	17.1 ± 7.0	(6A)	16.0 ± 9.6	(6B)	14.1 ± 5.7	(6C)		6B<8B
Scratchy periosteum	15.2 ± 7.6	(7A)	14.8 ± 8.2	(7B)	11.2 ± 4.0	(7C)		7B<8B, 7C<8C, 7C<2C
All previous 6 defects together	19.5 ± 8.4	(8A)	24.6 ± 13.5	(8B)	19.0 ± 8.1	(8C)		

Bonferroni test previously described and then a less conservative approach using degree of freedom adjustments. With the conservative Bonferroni approach, only two comparisons were significantly ($P<0.05$) different; 3B and 5B having less connective tissue than 8B. With the degree of freedom approach, the 8B (all 6 defects together - Weiler BCA) treatment had more connective tissue than all the other defect categories processed through the Weiler BCA system. When the Speco spiral groove plate was used, the connective tissue particles found in the formulation with scratchy periosteum was less than when excess bone (2C) and all 6 defects (8C) were added. The 5C formulation had less connective tissue than 2C and 3A contained less detectable connective tissue than 8A. All comparisons between the three processing methods within the particular defect categories were nonsignificant ($P>0.05$).

The three defect category formulations (PP-B-2120, bone, cartilage) that did not receive excess connective tissue still had considerable detected connective tissue regardless of processing method. This would imply that raw materials meeting the PP-B-2120 Interim Federal Specifications still contain a considerable amount of connective tissue that can be detected in this form of evaluation. It might also mean that a sizeable amount of the connective tissue detected by the panelists may have originated from sources (epimysium, etc.) that are not included in defects categories for connective tissue. Panelists trained to detect connective tissue of a given minimal size would have no way of determining the origin of the connective tissue. It would appear that to overcome this base level of background connective tissue and to thus detect increasing levels of connective tissue, then excessive levels of as many as 3 or 4 different types may be necessary. The question still exists as

to whether the "all previous 6 defects together" category represents the worst possible product in terms of defect levels.

Data presented in Table 10 deals with the evaluations provided by the descriptive attribute panel. Initial tenderness, connective tissue amount, juiciness and beef flavor intensity were all involved in significant (P<0.05) interactions of defect category and processing method and those means are given in Table 11. For final tenderness, the scratchy periosteum and all 6 defects together formulations yielded higher final tenderness scores than the backstrap and protruding tendon formulations. Regarding mouthcoating, panelists found less mouthcoating from the PP-B-2120 patties compared to the patties containing extra backstrap and abdominal tunic. Mean values are all close together and are thus of little practical importance. All sensory attributes had almost identical mean values according to the three processing methods.

The interaction mean values are given in Table 11. The very conservative Bonferroni test procedure was used to insure greater assurance of the validity of differences. For tenderness, 2A, 7C and 8C were rated as more tender than 5A and 6B was more tender than 4A and 5A. However, the range in initial tenderness values was only 0.6. Values for connective tissue were also quite similar and differences between mean values followed very little logic. The PP-B-2120-regular grind and all defects together-regular grind (should be most connective tissue) were found to have the least connective tissue. Only one difference (7C > 7A) was noted as significant (P<0.05) for juiciness. Differences in beef flavor intensity were more numerous with the range in mean values greater. Collectively, the three treatments made from the "all defects together" formulation had the highest intensity of beef flavor. Part of the reason

Table 10. Effects of defect category and processing method on descriptive attribute panel's sensory evaluation scores[c]

efect Category	Initial tenderness[a]	Final tenderness[d]	Connective tissue amount[a]	Juiciness[a]	Beef flavor intensity[a]	Mouth-coating[d]
P-B-2120	4.6	5.3	6.3	4.2	3.8	6.4
one	4.7	5.3	6.2	4.3	3.9	6.3
artilage	4.7	5.2	6.2	4.3	3.6	6.3
ackstrap	4.5	5.1	6.0	4.2	3.4	6.2
rotruding tendons	4.5	5.1	6.2	4.2	3.5	6.2
bdominal tunic	4.8	5.3	6.1	4.3	3.6	6.2
cratchy periosteum	4.7	5.4	6.2	4.3	3.6	6.2
ll previous 6 defects together	4.8	5.4	6.3	4.2	4.0	6.3
rocessing method[b]						
egular grind	4.7	5.3	6.2	4.2	3.7	6.3
eiler BCA	4.7	5.2	6.2	4.2	3.6	6.3
peco Spiral Grove	4.7	5.3	6.2	4.3	3.7	6.3

Sensory characteristic involved in a significant ($P<0.05$) interaction of defect category with processing method and is thus presented in Table 11.

All characteristics involved in a significant ($P<0.05$) interaction or were not affected by processing method.

Values based on 8-point systems where 8 = extremely tender, juicy, none in connective tissue, intense in flavor, while 1 = extremely tough, dry, abundant in connective tissue and bland in flavor.

Using the more conservative Bonferroni procedures, the differences for mouthcoating were PP-B-2120 > backstrap and abdominal tunic formulations. For final tenderness, the differences were that scratchy periosteum and all 6 defects together were more tender than backstrap and protruding tendon formulations.

Table 11. Interaction effects of defect category and processing method on descriptive attribute panel's sensory evaluation scores[e]

Defect Category code	Processing method code	Initial tenderness[a]	Connective tissue amount[b]	Juiciness[c]	Beef flavor intensity[d]
1	A	4.7	6.4	4.1	3.8
1	B	4.5	6.2	4.2	3.7
1	C	4.6	6.2	4.2	3.8
2	A	4.8	6.2	4.2	3.9
2	B	4.7	6.3	4.3	3.7
2	C	4.5	6.1	4.4	4.1
3	A	4.7	6.3	4.4	3.7
3	B	4.7	6.2	4.2	3.6
3	C	4.7	6.0	4.3	3.5
4	A	4.4	5.8	4.3	3.4
4	B	4.4	6.0	4.1	3.1
4	C	4.6	6.1	4.2	3.6
5	A	4.4	6.1	4.2	3.6
5	B	4.6	6.2	4.1	3.7
5	C	4.6	6.1	4.3	3.2
6	A	4.7	6.1	4.3	3.4
6	B	4.8	6.1	4.3	3.6
6	C	4.8	6.2	4.3	3.8
7	A	4.8	6.2	4.1	3.3
7	B	4.6	6.3	4.2	3.6
7	C	4.8	6.3	4.4	3.8
8	A	4.8	6.4	4.2	4.1
8	B	4.7	6.1	4.1	4.0
8	C	5.0	6.3	4.4	4.0

[a]Using the more conservative Bonferroni procedures, the differences for initial tenderness were 2A, 7C and 8A > 5A and 6B > 4A and 5A.

[b]Using the more conservative Bonferroni procedures, the differences for connective tissue amount were 1A > 3C, 4A and 4B and 4A < 1B, 1C, 2A, 2B, 3A, 3B, 6C, 7B, 7C, 8A and 8C.

[c]Using the more conservative Bonferroni procedures, the differences for juiciness were 7C > 7A.

[d]Using the more conservative Bonferroni procedures, the differences for beef flavor intensity were 4B < 1A, 1B, 1C, 2A, 2B, 2C, 3A, 3B, 5A, 5B, 6C, 7B, 7C, 8A, 8B, 8C; 5C < 1A, 1C, 2A, 2C, 3A, 5B, 6C, 7C, 8A, 8B, 8C; 7A < 1A, 2A, 2C, 6C, 7C, 8A, 8B, 8C; 4A < 2A, 2C, 8A, 8B, 8C; 3C < 2C, 8A; 4C < 2C, 8A; 5A < 8A; 6A < 2A, 2C, 8A, 8B, 8C; 6B < 2C, 8A; 6C > 7A; 7B < 8A; 8A > 3B.

[e]Values based on 8-point scales where 8 = extremely tender, juicy, none in connective tissue and intense in flavor, while 1 = extremely tough, dry, abundant in connective tissue and bland in flavor.

for proceeding on with descriptive attribute evaluations was the feeling from the sophisticated sensory approach first performed for the defects, that flavor differences existed. The reason for the higher ground beef flavor intensity noted for the "all defects together" treatments and general low intensity of ground beef flavor in all formulations is due to the considerable presence of an undesirable flavor best described as mature cow. This flavor was least prevalent in the "all defects together" formulation (Table 13); perhaps due to lean (which probably contained the mature cow flavor precursors) being substituted with high levels of connective tissue. Previous work in this Laboratory with restructured meats has shown increasing levels of connective tissue to have a positive effect on flavor. Other major flavors detected included liver and metallic. For many formulations, the combined total of these three flavors exceeded 80% of the "other than beef" flavors identified.

The data presented in Table 12 are soon to be published in the Journal of Food Science and were obtained from another study. It was designed to study adaptation and fatigue factors with sensory panelists, but also included some formulations that varied in raw materials. The differences obtained for tenderness and connective tissue were much greater in that study than in this present study dealing with defect levels including connective tissue. Those results would further question whether the levels of defect material have been extensive enough in this study.

The major differences in texture profile characteristics according to defect category seem to center on moistness, cohesiveness and type of breakdown (Table 14). The formulation made with excessive backstrap appeared to have high moistness on the surface of the patty, during first

Table 12. Mean values for ground beef patties obtained from recent study evaluating the effects of panelist fatigue and adaptation

Formulation	Initial tenderness[a]	Final tenderness[a]	Initial connective tissue amount[a]	Final connective tissue amount[a]	Juiciness[a]	% Fat
USDA Choice boneless chuck meat	4.8^{c}	5.3^{c}	4.6^{bc}	4.7^{b}	4.8^{c}	21.4
Boneless Utility cow shanks with USDA Choice boneless plates	4.9^{c}	5.2^{c}	4.3^{bc}	4.3^{bc}	4.9^{c}	19.6
Boneless Cow lean (90/10) with USDA Choice boneless plates	4.4^{c}	4.8^{d}	4.4^{bc}	4.6^{b}	4.5^{cd}	17.9
Strictly boneless cow lean	4.2^{c}	4.6^{d}	4.3^{bc}	4.6^{b}	4.0^{d}	10.6
USDA Choice boneless chuck meat with major connective tissue deposits removed	6.0^{b}	6.1^{b}	4.9^{b}	4.8^{b}	5.6^{b}	25.4
Boneless Utility cow shanks with considerable lean removed	4.7^{c}	4.9^{cd}	3.8^{c}	3.6^{c}	4.5^{cd}	12.2

[a]Values based on 8-point systems where 8 = extremely tender and juicy and none in connective tissue and 1 = extremely tough and dry and abudant in connective tissue.

[bcd]Means in the same column bearing different superscripts were significantly ($P<0.05$) different.

Table 13. Frequency of liver, metallic and mature cow flavors in beef patties according to defect category[a]

Defect Category	Liver flavor	Metallic flavor	Mature Cow flavor	Total of three flavors
PP-B-2120	22.7	26.9	25.2	74.8
Bone	15.6	22.9	31.2	69.7
Cartilage	19.3	28.6	39.5	87.4
Backstrap	20.1	16.6	43.9	80.6
Protruding tendons	19.1	25.2	40.5	84.8
Abdominal tunic	12.3	23.8	46.9	83.0
Scratchy periosteum	17.8	22.2	44.4	84.4
All previous 6 defects together	17.8	27.7	21.8	67.3

[a]Values are frequencies expressed as percentages of the occurrence of the three flavors in relation to all detected flavors within defect categories.

Table 14. Effects of defect category on texture profile panel scores[a]

Defect Category	Texture profile characteristic[a]							
	Moistness on surface patty	Rate of release during first bite[e]	Cohesiveness of chewed mass	Cohesiveness of chewed mass	Moistness of chewed mass	Rate of breakdown during chewing	Total number of chews	Toothpack after chewing
PP-B-2120	6.3^{bcd}	6.6	8.0^{b}	5.7^{cd}	5.7^{bc}	6.6^{bc}	39.0^{d}	2.7^{c}
Bone	6.4^{bcd}	5.9	8.7^{b}	6.6^{b}	5.8^{bc}	7.3^{bc}	42.6^{bcd}	3.1^{bc}
Cartilage	5.9^{cd}	5.9	8.4^{b}	6.2^{bc}	5.1^{c}	6.9^{bc}	45.5^{b}	3.2^{bc}
Backstrap	7.4^{b}	6.8	8.1^{b}	6.0^{cd}	6.5^{b}	6.3^{c}	45.2^{bc}	3.5^{bc}
Protruding tendons	6.5^{bcd}	6.0	8.6^{b}	5.4^{cd}	5.2^{bc}	7.0^{bc}	39.9^{cd}	3.3^{bc}
Abdominal tunic	6.8^{bcd}	6.6	7.4^{c}	6.0^{cd}	6.2^{bc}	6.6^{c}	41.6^{bcd}	2.8^{c}
Scratchy periosteum	7.3^{bc}	6.8	7.9^{b}	4.9^{d}	5.1^{c}	6.9^{bc}	40.0^{bcd}	3.2^{bc}
All previous 6 defects together	5.4^{d}	5.6	8.7^{b}	6.2^{bc}	5.6	8.0^{b}	43.7^{bcd}	4.0^{b}

[a]Refer to Table 4 for definitions of texture profile characteristics.

[bcd]Means in the same column with different superscripts are significantly ($P<0.05$) different by conservative Bonferroni test.

[e]Moisture release during first bite significant ($P<0.05$) through analysis of variance, but nonsignificant ($P>0.05$) differences were found through Bonferroni procedures.

bite and of the chewed mass. Patty samples from the abdominal tunic had lower cohesiveness of first bite values compared to the other formulations. Extra bone, cartilage and all defects together patties produced higher cohesiveness of chewed mass values than the scratchy periosteum patties. The fastest rate of breakdown was found for the all six defects together formulation; perhaps an indication that substitution of muscle with defect lessens the bindability of patties. This product also had the greatest toothpack, while patties from the PP-B-2120 treatment had the lowest toothpack. Processing method by itself exerted no effects ($P>0.05$) on texture profile characteristics.

Interaction effects ($P<0.05$) involving defect category and processing method are provided in Table 15 for texture profile characteristics. All of the visual characteristics involving distortion were affected by this interaction. For surface distortion, treatments 2B, 2C, 3A and 3B had high values. The Weiler BCA system seemed to produce more surface distortion in cooked patties made with extra bone, backstrap, protruding tendons and abdominal tunic. Differences in patty edge distortion did not appear to follow any logical trend. In some cases, the use of extra bone and cartilage seemed to produce higher scores for distortion of patty circumference with the Weiler BCA system. For juiciness, patties from the 3A formulation, had lower ratings than those obtained from 2B, 4A and 6C formulations.

All of the measured Instron values were significantly ($P<0.05$) affected by the defect category-processing method interaction (Table 16) Consistent or logical trends were not apparent. The range in mean values was not large, indicating, as expected, that the Instron is not a very precise instrument for measuring the effects of adding bone, cartilage

Table 15. Interaction effects of defect category and processing method on texture profile characteristics

Defect category code	Processing method code	Texture profile characteristic[a] Patty surface distortion[b]	Patty edge distortion[c]	Patty circumferance distortion[d]	Juiciness following seven chews[e]	Harshness of chewed mass[f]
1	A	4.4	4.0	4.0	5.1	6.3
1	B	3.3	3.3	4.3	4.9	5.7
1	C	5.1	4.5	4.1	5.1	7.1
2	A	4.7	6.1	6.1	4.7	6.0
2	B	6.2	5.8	5.1	6.8	6.2
2	C	6.4	5.7	6.1	4.4	7.4
3	A	6.2	5.2	5.8	3.2	8.1
3	B	6.0	5.5	5.8	4.8	6.9
3	C	5.4	5.8	6.3	4.6	7.2
4	A	5.4	6.0	5.5	7.0	6.3
4	B	5.5	5.4	5.4	5.8	6.7
4	C	3.8	3.7	3.7	5.6	7.0
5	A	3.5	3.0	3.6	4.0	7.2
5	B	5.3	5.1	4.7	4.4	7.3
5	C	4.4	4.5	4.2	4.9	6.8
6	A	4.3	4.2	3.8	4.7	6.9
6	B	5.0	5.0	6.1	5.6	6.9
6	C	3.7	4.0	4.3	6.6	5.8
7	A	4.5	3.9	5.0	4.8	7.8
7	B	3.9	3.9	2.9	4.7	6.2
7	C	4.0	4.0	4.1	4.4	6.2
8	A	5.1	5.9	5.6	5.1	7.2
8	B	5.2	6.8	7.1	4.7	7.6
8	C	5.7	5.1	4.7	5.0	5.5

[a]Refer to Table 4 for definitions of texure profile characteristics.

[b]Numerous significant ($P<0.05$) differences found even with Bonferroni's test. Most of the differences centered on defect-processing codes 2B, 2C, 3A, 3B, having more surface distortion than other treatments.

[c]Using the bonferroni procedures, the significant ($P<0.05$) differences were: 1B < 2A, 2B, 3B, 3C, 4A, 8A, 8B; 2A > 4C, 5A; 5A < 2A, 2B, 2C, 3B, 3C, 4A, 8A, 8B, 8C; 4A > 4C; 4C < 8B; 6A, 6C, 7A, 7B, 7C < 8B.

[d]Numerous significant ($P<0.05$) differences found. Most of the differences centered on 4C, 5A and 7B having less distortion than other defect-processing codes.

[e]Using the Bonferroni procedures, the significant ($P<0.05$) differences were 3A < 2B, 4A and 6C.

[f]While analysis of variance was significant ($P<0.05$), nonsignificant ($P>0.05$) differences were found through Bonferroni procedures.

Table 16. Interaction effects of defect category and processing method on Instron values[a]

Defect Category code	Processing method code	Peak load, kg	Peak energy	Modulus of elasticity	Fail energy	Newtons cm^2
1	A	12.4	7.2	25.2	12.1	29.2
1	B	13.6	7.9	25.9	13.5	32.1
1	C	13.6	7.9	24.1	13.8	30.8
2	A	14.4	8.1	25.9	13.7	33.2
2	B	13.8	8.0	26.2	14.2	32.3
2	C	15.6	8.3	23.2	14.8	37.3
3	A	13.8	8.1	26.8	13.6	33.3
3	B	14.8	7.8	26.4	13.6	36.3
3	C	16.1	8.9	25.8	15.6	37.0
4	A	14.9	8.3	26.5	14.2	34.7
4	B	14.6	7.9	26.2	14.0	34.1
4	C	13.7	7.6	27.4	13.3	32.6
5	A	15.3	8.4	27.1	14.6	36.5
5	B	14.1	8.0	26.6	13.6	32.0
5	C	13.8	8.1	23.8	13.9	31.3
6	A	14.4	8.0	23.9	14.0	33.8
6	B	15.2	8.3	24.9	14.5	37.4
6	C	13.2	7.6	25.3	12.9	31.9
7	A	15.2	7.9	27.3	13.7	37.1
7	B	14.0	7.8	28.0	12.8	34.9
7	C	13.7	7.5	27.5	12.5	33.9
8	A	12.8	6.8	22.6	12.3	30.7
8	B	15.8	7.6	24.0	13.8	37.8
8	C	14.8	7.3	26.0	13.0	36.6

[a]Significant ($P<0.05$) interaction of defect category and processing method.

and connective tissue defects. There was a tendency for the values to be slightly lower for the PP-B-2120 formulation.

Cooking losses were also involved in an interaction ($P<0.05$) between defect category and processing method (Table 17). There was close agreement in many of the values between the Instron patties and sensory patties. However, as with many of the sensory and Instron values, there did not seem to be any particular trend to the differences among the formulations.

Following six months of frozen storage, the patties were evaluated for shelflife and storage properties. The frequency of lean color scores are presented in Table 18 for defect categories. Frequency distributions for lean color did not appreciably differ between the defect categories. Likewise, the color distributions did not change between the processing systems (Table 19).

Other indicators of storage deterioration as affected by the interaction of defect category and processing method are provided in Table 20. For surface discoloration, it would appear that the interaction arose due to the fact that the Weiler BCA system produced more surface discoloration in some defect categories (1B, 4B, 5B, 7B, 8B) and less in others (2B, 3B). For TBA values, the biggest differences occurred with the lower values obtained for 4B, 4C, 7A, 7B, 8A and 8B vs 1A, 1B and 5B. It would appear that defect category was exerting as much a role on TBA values as processing method. However, all the TBA values are quite low and close together, and thus, the differences are of little practical value. These low TBA values were supported by the sensory panel data for flavor, which showed only an infrequent detection of rancidity. It was somewhat surprising to find such low values following six months of

Table 17. Interaction effects of defect category and processing method on cooking losses[a]

Defect Category code	Processing method code	Cooking loss from sensory panel, % n = 32	Cooking loss from Instron patties, % n = 20
1	A	42.3 ± 1.3	41.7
1	B	41.4 ± 1.4	42.4
1	C	40.6 ± 1.7	41.1
2	A	45.0 ± 1.5	46.2
2	B	42.4 ± 1.9	44.4
2	C	42.8 ± 1.2	43.6
3	A	42.6 ± 1.7	42.4
3	B	42.4 ± 1.6	42.1
3	C	42.3 ± 1.5	43.8
4	A	41.6 ± 1.4	42.9
4	B	40.8 ± 1.6	41.1
4	C	41.4 ± 1.6	40.7
5	A	41.5 ± 1.5	41.7
5	B	40.7 ± 1.0	39.9
5	C	37.4 ± 1.8	38.8
6	A	41.4 ± 1.4	41.4
6	B	41.5 ± 1.2	42.8
6	C	41.8 ± 1.2	43.0
7	A	40.7 ± 1.7	41.9
7	B	40.2 ± 1.4	41.1
7	C	41.8 ± 1.7	42.9
8	A	41.4 ± 1.4	39.7
8	B	40.7 ± 1.0	40.9
8	C	43.2 ± 1.5	42.8

[a]Significant ($P<0.05$) interaction of defect category and processing method.

Table 18. Frequency of lean color scores in beef patties according to defect category[a]

	Color							
Defect category	Very light grayish red	Light grayish red	Moderately light Cherry red	Cherry red	Slightly dark red	Moderately dark red	Dark red	Very Dark red
PP-B-2120	0.0	9.9	19.8	12.1	18.7	16.5	19.8	3.3
Bone	2.0	15.3	17.4	10.2	17.4	15.3	17.4	5.1
Cartilage	7.5	14.0	18.3	8.6	15.1	15.0	15.0	6.4
Backstrap	1.1	11.0	19.8	12.1	19.8	16.5	16.5	3.3
Protruding tendons	3.5	10.6	18.8	11.8	17.6	16.5	15.3	5.9
Abdominal tunic	0.0	9.6	19.2	13.8	19.2	14.9	17.0	6.4
Scratchy periosteum	6.5	18.4	19.6	9.8	18.5	13.0	10.9	3.3
All previous 6 defects together	4.6	11.5	18.4	11.5	18.4	14.9	16.1	4.6

[a]Values are frequencies expressed as percentages of the occurrence of each color in relation to all colors within a defect category.

Table 19. Frequency of lean color scores in beef patties according to processing method[a]

Processing method	Color							
	Very light grayish red	Light grayish red	Moderately light Cherry red	Cherry red	Slightly dark red	Moderately dark red	Dark red	Very Dark red
Regular grinder plate	4.8	14.9	19.0	8.9	17.7	15.3	14.9	4.4
Weiler BCA	0.4	11.6	18.2	12.8	17.8	15.7	16.9	6.6
Speco Spiral grove plate	4.2	11.2	19.5	12.0	18.7	14.9	16.2	3.3

[a]Values are frequencies expressed as percentages of the occurrence of each color in relation to all colors within a processing method.

Table 20. Interaction effects of defect category and processing method on surface discoloration scores, TBA values and aerobic plate counts

Category code	Processing method code	Surface Discoloration scores[a]	TBA values[b]	Surface plate counts/g[c]
1	A	4.7	0.31	33,367
1	B	3.9	0.24	77,533
1	C	4.9	0.29	34,667
2	A	4.9	0.26	6,867
2	B	5.4	0.24	9,000
2	C	4.4	0.23	84,667
3	A	4.0	0.19	6,267
3	B	4.8	0.26	131,000
3	C	4.5	0.22	30,333
4	A	4.4	0.21	29,333
4	B	3.8	0.12	11,367
4	C	4.6	0.14	41,667
5	A	4.0	0.17	54,667
5	B	3.6	0.28	37,667
5	C	4.2	0.26	27,667
6	A	4.6	0.18	10,267
6	B	4.2	0.23	23,000
6	C	4.1	0.18	36,000
7	A	4.3	0.11	4,370
7	B	4.0	0.14	2,633
7	C	4.3	0.19	4,433
8	A	3.6	0.13	6,200
8	B	2.8	0.20	17,300
8	C	4.0	0.13	23,000

[a]Numerous significant ($P<0.05$) differences were found by Bonferroni's test. Most differences consisted of 8B having more surface discoloration than all formulations except for 4B and 5B. Treatment 2B had less surface discoloration than many of the other formulations.

[b]Numerous significant ($P<0.05$) differences were found by Bonferroni's test. Most differences involved 4B, 4C, 7A, 7B, 8A, 8C having lower TBA values than 1A, 1B, 5B.

[c]Not subjected to statistical analyses.

frozen storage in the original boxes. Aerobic plate counts were generally low (lowest for scratchy periosteum) and do not follow any particular pattern according to defect category and processing method.

Off-odor scores were affected by defect category (Table 21) with the major differences being that the PP-B-2120, extra bone and extra scratchy periosteum formulations had less (really none) off-odor than the formulations with extra cartilage and protruding tendons.

Table 21. Off-odor scores according to defect category

Defect category	Defect Code number	Off-odor scores	Comparisons significant at $P<0.05$
PP-B-2120	1	4.0	1 > 3,5
Bone	2	4.0	2 > 3,5
Cartilage	3	3.8	3 < 1,2,7
Backstrap	4	3.9	4 > 5
Protruding tendons	5	3.8	5 < 1,2,4,6,7,8
Abdominal tunic	6	3.9	6 > 5
Scratchy periosteum	7	4.0	7 > 3,5
All previous 6 defects together	8	3.9	8 > 5

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